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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventorship..... Horowitz et al.
Applicant..... Rambus Inc.
Attorney's Docket No. RB1-003US
Title: Method and Apparatus for Transmitting Data with Reduced Coupling Noise

TRANSMITTAL LETTER AND CERTIFICATE OF MAILING

To: Commissioner of Patents and Trademarks
Washington, D.C. 20231

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The following enumerated items accompany this transmittal letter and are being submitted for the matter identified in the above caption.

1. Transmittal Letter with Certificate of Mailing included.
2. PTO Return Postcard Receipt
3. Check in the Amount of \$1,234.00
4. Fee Transmittal
5. New patent application (title page plus 20 pages, including claims 1-35 & Abstract)
6. Executed Declaration
7. 6 sheets of formal drawings (Figs. 1-6)
8. Assignment w/Recordation Cover Sheet

Large Entity Status ☒ [x]

Small Entity Status ☐ []

The Commissioner is hereby authorized to charge payment of fees or credit overpayments to Deposit Account No. 12-0769 in connection with any patent application filing fees under 37 CFR 1.16, and any processing fees under 37 CFR 1.17.

Date: 6-14-00

By: 

Steven R. Sponseller
Reg. No. 39,384

CERTIFICATE OF MAILING

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Express Mail No. (if applicable) EL6 2435 1820

Date: June 14 2000

By: 

Lori A. Vierra

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

APPLICATION FOR LETTERS PATENT

**Method and Apparatus for Transmitting Data
with Reduced Coupling Noise**

Inventors:

Mark A. Horowitz

Donald V. Perino

ATTORNEY'S DOCKET NO. RB1-003US

TECHNICAL FIELD

The present invention relates to the transmission of data. More specifically, the present invention reduces coupling noise between conductors by using particular routing patterns for the conductors and/or modifying the coupling such that the transmitter coupling is approximately the same as the receiver coupling.

BACKGROUND

Transmission lines often suffer from crosstalk which results from the parasitic coupling between nearby conductors. The coupling between the conductors can be either capacitive or inductive in nature and is typically associated with integrated circuit packages, connectors, and printed circuit traces positioned in parallel with one another.

A particular type of data transmission system transmits signals differentially along pairs of conductors. A differential driver receives data at an input and generates a corresponding differential signal on a pair of outputs (i.e., an inverting output and a non-inverting output). The differential signal is transmitted across a pair of conductors and received by a differential receiver, which rejects signals that are present on both conductors (referred to as common mode signals). This differential transmission system helps reduce noise that is induced on both conductors, however coupling noise still exists on the conductors. For example, a differential pair of conductors is likely to have noise when passing through a connector. As transmission rates increase, the resulting increase in signal edge rates will aggravate this problem.

Existing techniques to reduce coupling between conductors include adding

1 ground conductors between signal conductors or positioning the signal conductors
2 farther away from one another. However, the addition of ground conductors
3 between signal conductors increases the number of conductors, thereby increasing
4 the cost and complexity of the system. Further, if the conductors are traces on a
5 printed circuit board, the addition of ground conductors between signal conductors
6 increases the printed circuit board area required to route all of the conductors.
7 Positioning the signal conductors farther away from one another increases the size
8 of the printed circuit board, connector, integrated circuit package, or other device
9 that handles the conductors.

10 Fig. 1 illustrates a prior art system in which inductive coupling occurs
11 between various conductors. The system uses differential signaling to transmit
12 three bits of data across three differential line pairs. The inductors shown coupled
13 in series with the various conductors represent the inductances inherent in the
14 conductors. The three data bits are designated as a, -a, b, -b, c, and -c. An
15 integrated circuit 100 receives or generates the three data bits that are provided to
16 differential drivers 108, 110, and 112. The signals generated by the differential
17 drivers 108-112 are transmitted through a connector 102, another connector 104,
18 to another integrated circuit 106. Each of the three pairs of conductors is coupled
19 to one of three differential receivers 114, 116, or 118, which are contained in
20 integrated circuit 106. For example, the system shown in Fig. 1 may be a
21 backplane having the connectors 102 and 104 mounted to the backplane. In this
22 example, integrated circuits 100 and 106 are mounted on a substrate (such as a
23 printed circuit board) which is electrically coupled to one of the connectors 102,
24 104.
25

1 In the example of Fig. 1, coupling noise is caused by inductive coupling.
2 This coupling corresponds to parasitic mutual inductance which occurs due to the
3 physical construction of the integrated circuit packages and connectors in the
4 system. In Fig. 1, the mutual inductance is represented by inductive coupling
5 coefficient K1, K2, and K3. Since the two connectors 102 and 104 are the same,
6 they have the same inductive coupling coefficient (K2). The two integrated circuit
7 packages 100 and 106 are different, so they each have a different inductive
8 coupling coefficient (K1 and K3).

9 The signal quality in the system of Fig. 1 is degraded due to the parasitic
10 mutual inductance. For example, if signals a, -a and c, -c switch while signals
11 b, -b are quiet, a noise signal will appear at the receiver end of the line carrying b,
12 -b. This type of noise signal reduces the timing and voltage margins of data
13 arriving at the differential receiver 114, 116 or 118.

14 The system and method described herein addresses these and other
15 problems by reducing the coupling noise on conductors positioned near one
16 another.

18 SUMMARY

19 In one embodiment, a first device is coupled to a first connector. A second
20 connector is coupled to the first connector through multiple conductors, in which
21 alternating pairs of conductors are reversed. A second device is coupled to the
22 second connector through a second group of multiple conductors.

23 In another embodiment, the first device includes multiple differential
24 drivers to transmit differential signals.
25

1 In a particular implementation of the system, the second device includes
2 multiple differential receivers to receive multiple differential signals.

3 Another embodiment provides that the inductive coupling of the first device
4 is substantially the same as the inductive coupling of the second device.

5 In a particular embodiment, alternating pairs of conductors in the second
6 group of multiple conductors are reversed.

7
8 In a described implementation, a transmitter package is modified such that
9 the coupling coefficient of the transmitter package is substantially the same as the
10 coupling coefficient of a receiver package. Multiple pairs of differential signals
11 are transmitted using the transmitter package. The receiver then receives and
12 decodes the multiple pairs of differential signals.

13 **BRIEF DESCRIPTION OF THE DRAWINGS**

14
15 Fig. 1 illustrates a prior art system in which inductive coupling occurs
16 between various conductors.

17 Fig. 2 illustrates an embodiment of a system that reduces coupling noise.

18 Fig. 3 illustrates a pair of connectors coupled together with multiple pairs
19 of transmission lines.

20 Fig. 4 is a flow diagram illustrating a procedure for reducing coupling noise
21 between conductors.

22 Fig. 5 illustrates another embodiment of a system that reduces coupling
23 noise between conductors.

24 Fig. 6 is a flow diagram illustrating another procedure for reducing
25 coupling noise between conductors.

DETAILED DESCRIPTION

The method and apparatus for transmitting data with reduced coupling noise (both inductive coupling and capacitive coupling) described herein routes the signal conductors in a particular manner to reduce the inductive coupling between signal conductors. Additionally, the transmitter coupling is modified to be approximately the same as the receiver coupling to reduce the inductive coupling between signal conductors. Particular examples herein are described with reference to integrated circuits and connectors. However, the teachings of the present invention can be applied to any type of device coupled to any type of interconnection mechanism.

Fig. 2 illustrates an embodiment of a system that reduces inductive coupling noise. An integrated circuit 200 receives or generates three data bits (labeled a, -a, b, -b, c, and -c), and contains three differential drivers 208, 210, and 212. Each of the three pairs of signal conductors is coupled to one of the three differential drivers. Differential drivers 208-212 may also be referred to as differential transmitters. The integrated circuit 200 can be any type of integrated circuit such as a memory device, a processor, an ASIC, or programmable logic devices. The signal conductors used to transmit data may include wires, cables, traces on a printed circuit board, conductors embedded within a substrate (e.g., between different layers of a substrate), and various other conductive materials.

The signals generated by the differential drivers 208-212 are transmitted through a connector 202, another connector 204, to another integrated circuit 206. Integrated circuit 206 contains three differential receivers 214, 216, and 218, each coupled to receive a different pair of signal conductors. Differential receivers 214-

1 218 may also be referred to as differential decoders. The connectors 202 and 204
2 can be any type of electrical connecting device capable of coupling with at least
3 one component, such as a mating connector, a substrate, an edge of a printed
4 circuit board, etc.

5 In a particular embodiment, the system of Fig. 2 is a backplane having
6 multiple connectors (e.g., connectors 202 and 204) electrically coupled to the
7 backplane. The backplane is a printed circuit board, which can be manufactured
8 using any type of substrate capable of supporting the multiple connectors and
9 multiple conductors that interconnect the multiple connectors. The backplane may
10 be a multi-level board having multiple layers of substrate materials and/or
11 conductive materials. In this embodiment, the integrated circuits 200 and 206 are
12 mounted on another substrate (e.g., a printed circuit board or "card") that is
13 electrically coupled to the corresponding connector 202 or 204. In a particular
14 configuration, integrated circuits 200 and 206 are memory devices (either volatile
15 or non-volatile memory devices), each of which is mounted on a printed circuit
16 board. The memory device and printed circuit board combination may be referred
17 to as a memory module. Any number of memory modules can be electrically
18 coupled to connectors mounted to a backplane.

19 As shown in Fig. 2, the two outer differential pairs (i.e., a, -a and c, -c)
20 have a polarity reversal (also referred to as a "twist" or a conductor reversal)
21 between the two connectors 202 and 204. This polarity reversal significantly
22 reduces (or eliminates) the coupling noise of the two connectors 202 and 204
23 because any coupling noise added by connector 202 is subtracted by connector
24 204. The polarity is reversed again between connector 204 and integrated circuit
25

1 206. This second polarity reversal ensures that the differential receiver receives
2 the inverted and non-inverted signals on the appropriate input pins.

3 In an alternate embodiment, the second polarity reversal is not necessary
4 because the polarity of the input connections to the differential receiver is
5 reversed. For example, in the orientation shown in Fig. 2, without the second
6 polarity reversal, the "a" signal (non-inverted) would be coupled to the inverted
7 input to the differential receiver 214 and the "-a" signal (inverted) would be
8 coupled to the non-inverted input to the differential receiver 214. However, if the
9 orientation of the differential receiver 214 is reversed such that the positions of the
10 inputs to the differential receiver are reversed, then the second polarity reversal of
11 the signal conductors is not necessary.

12 Fig. 3 illustrates a pair of connectors 230 and 232 coupled together with
13 multiple pairs of conductors. As shown in Fig. 3, alternating pairs of conductors
14 have reversed polarity. As discussed above, this reversed polarity significantly
15 reduces (or eliminates) the coupling noise induced by the two connectors
16 because any coupling noise added by one connector is subtracted by the other
17 connector. The top pair of conductors 234 and 236 have their polarity reversed.
18 The next pair of conductors 238 and 240 are not reversed. The next pair of
19 conductors have a reversed polarity, and the next pair is not reversed. This pattern
20 of reversing the polarity of alternating pairs of conductors continues until the last
21 pair of conductors. In the example of Fig. 3, seven pairs of conductors are
22 illustrated. However, the teachings of the present invention can be applied to
23 systems having any number of pairs of conductors coupled between two
24 connectors.
25

1 Additionally, in the example of Fig. 3, the polarity reversals are shown
2 approximately midway between the two connectors 230 and 232. However, in
3 alternate embodiments, the polarity reversals may be located anywhere between
4 the two connectors 230 and 232. Further, the polarity reversals need not occur at
5 the same location. For example, a first polarity reversal may occur close to
6 connector 230, a second polarity reversal may occur midway between the two
7 connectors 230 and 232, and a third polarity reversal may occur close to the
8 connector 232.

9 Fig. 4 is a flow diagram illustrating a procedure for reducing coupling noise
10 between conductors. First, an integrated circuit generates multiple pairs of
11 differential signals (block 250). A first connector generates inductive coupling
12 noise as the differential signals are transmitted through the first connector (block
13 252). Next, the procedure reverses the polarity of alternating pairs of differential
14 signal conductors (block 254). A second connector generates inductive coupling
15 noise opposite the noise generated by the first connector as the differential signals
16 are transmitted through the second connector (block 256). The procedure then
17 reverses the polarity of alternating pairs of differential signal conductors (block
18 258). The pairs of signal conductors reversed in block 258 are the same as those
19 reversed in block 254. Finally, the procedure decodes the multiple pairs of
20 differential signals.

21 Fig. 5 illustrates another embodiment of a system that reduces coupling
22 noise between conductors. The system illustrated in Fig. 5 is similar to the system
23 illustrated in Fig. 2. An integrated circuit 300 includes three differential drivers
24 308, 310, and 312. Integrated circuit 300 may also be referred to as the transmitter
25 package because it transmits the signals. The signals generated by the differential

1 drivers 308-312 are transmitted through a connector 302, another connector 304,
2 to another integrated circuit 306, which includes three differential receivers 314,
3 316, and 318. Integrated circuit 306 may also be referred to as the receiver
4 package because it receives the signals from the transmitter package (i.e.,
5 integrated circuit 300).

6 In the embodiment of Fig. 5, the polarity of alternating pairs of conductors
7 (i.e., a, -a and c, -c) is reversed between the two connectors 302 and 304.
8 However, there is no corresponding polarity reversal between connector 304 and
9 integrated circuit 306, as shown in Fig. 2. Also, the inductive coupling between
10 conductors in integrated circuit 300 is K3, which is the same inductive coupling as
11 in integrated circuit 306. In this embodiment, the inductive coupling noise caused
12 by the two connectors 302 and 304 is significantly reduced due to the polarity
13 reversal in the conductors, as discussed above. Further, the inductive coupling
14 noise caused by the two integrated circuits 300 and 306 is reduced because the two
15 integrated circuits have substantially the same inductive coupling coefficient.

16 The system shown in Fig. 5 is designed to provide symmetric coupling
17 between the two halves of the transmission lines (i.e., integrated circuit 300 and
18 connector 302 represent one half, and connector 304 and integrated circuit 306
19 represent the other half. The symmetry between the two connectors 302 and 304
20 is provided by the polarity reversal between the two connectors. Similarly, the
21 symmetry between the two integrated circuits 300 and 306 is provided by the same
22 coupling in the two integrated circuits.

23 In a particular system, the receiver package (i.e., integrated circuit 306) has
24 more coupling than the transmitter package (i.e., integrated circuit 300). To
25 provide the necessary symmetry, the coupling of the transmitter package is

1 increased (i.e., more coupling noise is generated) to match the coupling of the
2 receiver package. The coupling coefficient of the transmitter package can be
3 increased by redesigning the package of the integrated circuit so that the coupling
4 coefficient of the transmitter package is substantially similar to the coupling
5 coefficient of the receiver package. For example, in a typical integrated circuit
6 package, crosstalk results from the inductive coupling between bond wires. The
7 inductive coupling is proportional to the length of the bond wires, in which longer
8 bond wires have greater inductive coupling. Thus, the coupling coefficient of the
9 transmitter package can be increased by increasing the bond wire length.

10 As shown in Fig. 5, the polarity of the conductors is not reversed between
11 connector 304 and integrated circuit 306 (as was the case in Fig. 2). However, the
12 orientation of the differential receivers 314 and 318 is reversed such that the
13 inverted signal (-a and -c) is coupled to the inverted input of the differential
14 receiver and the non-inverted signal (a and c) is coupled to the non-inverted input
15 of the differential receiver. Note that the orientation of differential receiver 316 is
16 not reversed because the associated pair of conductors were not reversed between
17 the two connectors 302 and 304.

18 In an alternative embodiment, the orientation of differential receivers 314
19 and 318 is not changed. Thus, the inverted signals are coupled to the non-inverted
20 inputs and the non-inverted signals are coupled to the inverted inputs. Thus, the
21 differential receivers 314 and 318 generate incorrect outputs (i.e., the opposite of
22 the actual value). This is easily corrected by coupling an inverter to the output of
23 each differential receiver 314 and 318. The output of the inverter is the correct
24 output for the system.
25

1 In another embodiment, two integrated circuits (e.g., integrated circuits 300
2 and 306) are coupled to one another through multiple pairs of conductors (i.e., a
3 chip-to-chip link). As mentioned above, the inductive coupling coefficient of the
4 first integrated circuit is designed to be substantially the same as the inductive
5 coupling coefficient of the second integrated circuit. In this embodiment, no
6 connectors are located between the two integrated circuits. This configuration
7 provides for the reversing of polarities on alternating line pairs, in the manner
8 discussed. Thus, instead of reversing polarities of signal lines between two
9 connectors, this configuration reverses the polarity of signal lines coupled between
10 the two integrated circuits.

11 Fig. 6 is a flow diagram illustrating another procedure for reducing
12 coupling noise between conductors. The flow diagram shown in Fig. 6
13 corresponds to the system shown in Fig. 5. First, the transmitter package is
14 modified such that the coupling coefficient of the transmitter package is
15 substantially the same as the receiver package (block 350). The transmitter
16 package generates multiple pairs of differential signals (block 352). A first
17 connector generates inductive coupling noise as the differential signals are
18 transmitted through the first connector (block 354). Next, the procedure reverses
19 the polarity of alternating pairs of differential signal conductors (block 356). A
20 second connector generates inductive coupling noise opposite to the noise
21 generated by the first connector as the differential signals are transmitted through
22 the second connector (block 358). Finally, the procedure decodes the multiple
23 pairs of differential signals (block 360).

24 Thus, a system has been described that reduces inductive coupling noise
25 between conductors. The noise reduction is accomplished by reversing alternating

1 pairs of conductors and/or modifying the coupling of the integrated circuit
2 packages such that the transmitter coupling is substantially the same as the
3 receiver coupling.

4 Although the description above uses language that is specific to structural
5 features and/or methodological acts, it is to be understood that the invention
6 defined in the appended claims is not limited to the specific features or acts
7 described. Rather, the specific features and acts are disclosed as exemplary forms
8 of implementing the invention.

CLAIMS

1. An apparatus comprising:
 - a first device;
 - a first connector coupled to the first device;
 - a second connector coupled to the first connector through a first plurality of conductors, wherein alternating pairs of conductors are reversed; and
 - a second device coupled to the second connector through a second plurality of conductors.
2. An apparatus as recited in claim 1 wherein the first device includes a plurality of differential drivers.
3. An apparatus as recited in claim 1 wherein the second device includes a plurality of differential receivers.
4. An apparatus as recited in claim 1 wherein the first device is an integrated circuit.
5. An apparatus as recited in claim 1 wherein the first device is an integrated circuit disposed on a substrate, wherein the substrate is electrically coupled to the integrated circuit and the first connector.
6. An apparatus as recited in claim 1 wherein the second device is an integrated circuit.

1 7. An apparatus as recited in claim 1 wherein the first device has an
2 inductive coupling coefficient substantially the same as the inductive coupling
3 coefficient of the second device.
4

5 8. An apparatus as recited in claim 1 wherein the alternating pairs of
6 conductors are reversed once between the first connector and the second
7 connector.
8

9 9. An apparatus as recited in claim 1 wherein alternating pairs of
10 conductors in the second plurality of conductors are reversed.
11

12 10. An apparatus comprising:
13 a first integrated circuit including a plurality of differential drivers;
14 a first connector coupled to the first integrated circuit;
15 a second connector coupled to the first connector through a plurality of
16 electrical conductors, wherein alternating pairs of the electrical conductors are
17 reversed; and
18 a second integrated circuit coupled to the second connector, wherein the
19 second integrated circuit includes a plurality of differential receivers.
20

21 11. An apparatus as recited in claim 10 further comprising a second
22 plurality of electrical conductors coupled between the second connector and the
23 second integrated circuit, wherein alternating pairs of the second plurality of
24 electrical conductors are reversed.
25

1 **12.** An apparatus as recited in claim 10 further comprising a second
2 plurality of electrical conductors coupled between the second connector and the
3 second integrated circuit, wherein each pair of conductors includes an inverted
4 conductor and a non-inverted conductor, each inverted conductor coupled to a
5 non-inverted input of one of the differential receivers, and each non-inverted
6 conductor coupled to an inverted input of one of the differential receivers.

7
8 **13.** An apparatus as recited in claim 10 wherein the first integrated
9 circuit has an inductive coupling coefficient substantially the same as the inductive
10 coupling coefficient of the second integrated circuit.

11
12 **14.** An apparatus as recited in claim 10 wherein the alternating pairs of
13 electrical conductors are reversed once between the first connector and the second
14 connector.

15
16 **15.** An apparatus comprising:
17 a printed circuit board;
18 a plurality of connectors disposed on the printed circuit board;
19 a first integrated circuit disposed on a first substrate, wherein the first
20 substrate is configured to be coupled to one of the plurality of connectors;
21 a second integrated circuit disposed on a second substrate, wherein the
22 second substrate is configured to be coupled to one of the plurality of connectors;
23 and
24
25

1 a first plurality of electrical conductors coupled to the plurality of
2 connectors, wherein alternating pairs of conductors between adjacent connectors
3 have reversed polarity.
4

5 **16.** An apparatus as recited in claim 15 wherein the printed circuit board
6 is a backplane.
7

8 **17.** An apparatus as recited in claim 15 further comprising a second
9 plurality of conductors coupled between the first integrated circuit and one of the
10 plurality of connectors, wherein alternating pairs of conductors have reversed
11 polarity.
12

13 **18.** An apparatus as recited in claim 15 wherein the first substrate is a
14 printed circuit board.
15

16 **19.** An apparatus as recited in claim 15 wherein the first substrate is a
17 memory module.
18

19 **20.** An apparatus as recited in claim 15 wherein the first integrated
20 circuit is a memory device.
21

22 **21.** An apparatus as recited in claim 15 wherein the first integrated
23 circuit has an inductive coupling substantially the same as the inductive coupling
24 of the second integrated circuit.
25

1 **22.** An apparatus comprising:
2 a first device; and
3 a second device coupled to the first device through a plurality of electrical
4 conductors, wherein the inductive coupling coefficient of the first device is
5 adjusted to be substantially the same as the inductive coupling coefficient of the
6 second device.

7
8 **23.** An apparatus as recited in claim 22 wherein the first device includes
9 a plurality of differential drivers, wherein each differential driver is coupled to a
10 pair of electrical conductors.

11
12 **24.** An apparatus as recited in claim 22 wherein the second device
13 includes a plurality of differential receivers, wherein each differential receiver is
14 coupled to a pair of electrical conductors.

15
16 **25.** An apparatus as recited in claim 22 further comprising a pair of
17 connectors coupled between the first device and the second device, wherein a
18 second plurality of electrical conductors are coupled between the pair of
19 connectors, and wherein alternating pairs of electrical conductors are reversed.

20
21 **26.** A method comprising:
22 generating a plurality of differential signals;
23 transmitting the plurality of differential signals through a first connector
24 and a second connector to a plurality of differential receivers;
25

1 reversing the polarity of alternating differential signals between the first
2 and second connectors; and

3 reversing the polarity of alternating differential signals between the second
4 connector and the plurality of differential receivers.
5

6 **27.** A method as recited in claim 26 wherein the first connector
7 generated inductive coupling noise as the differential signals are transmitted
8 through the first connector.
9

10 **28.** A method as recited in claim 26 wherein the second connector
11 generated inductive coupling noise opposite the noise generated by the first
12 connector as the differential signals are transmitted through the second connector.
13

14 **29.** A method as recited in claim 26 further including decoding the
15 plurality of differential signals.
16

17 **30.** A method as recited in claim 26 wherein a transmitter package
18 transmits the plurality of differential signals and a receiver package receives the
19 plurality of differential signals.
20

21 **31.** A method as recited in claim 30 further including modifying the
22 transmitter package such that the coupling coefficient of the transmitter package is
23 substantially the same as the receiver package.
24
25

1 **32.** A method comprising:

2 modifying a transmitter package such that the coupling coefficient of the
3 transmitter package is substantially the same as the coupling coefficient of a
4 receiver package;

5 transmitting multiple pairs of differential signals using the transmitter
6 package; and

7 receiving the multiple pairs of differential signals using the receiver
8 package.

9
10 **33.** A method as recited in claim 32 wherein the transmitter package
11 transmits multiple pairs of differential signals across a plurality of conductors.

12
13 **34.** A method as recited in claim 32 further comprising decoding the
14 multiple pairs of differential signals.

15
16 **35.** A method as recited in claim 32 wherein the differential signals are
17 transmitted through a pair of connectors on a plurality of conductors, wherein
18 alternating pairs of conductors are reversed between the pair of connectors.

1 **ABSTRACT**

2 A first integrated circuit is coupled to a first connector. A second connector
3 is coupled to the first connector through multiple conductors, in which alternating
4 pairs of conductors are reversed. A second integrated circuit is coupled to the
5 second connector through a second group of conductors. The first integrated
6 circuit includes multiple differential drivers and the second integrated circuit
7 includes multiple differential receivers. The inductive coupling coefficient of the
8 first device is modified to be substantially the same as the inductive coupling
9 coefficient of the second device.
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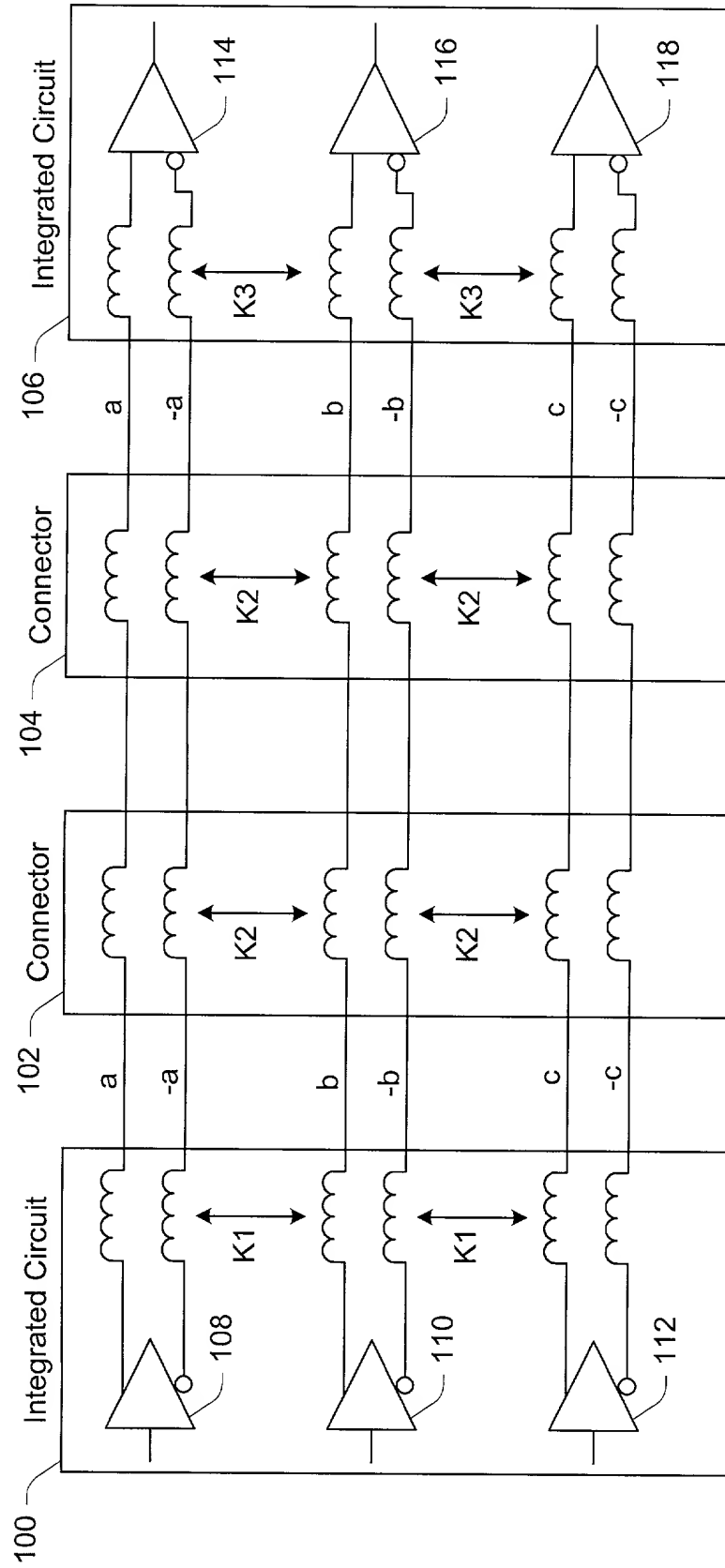


Fig. 1
(Prior Art)

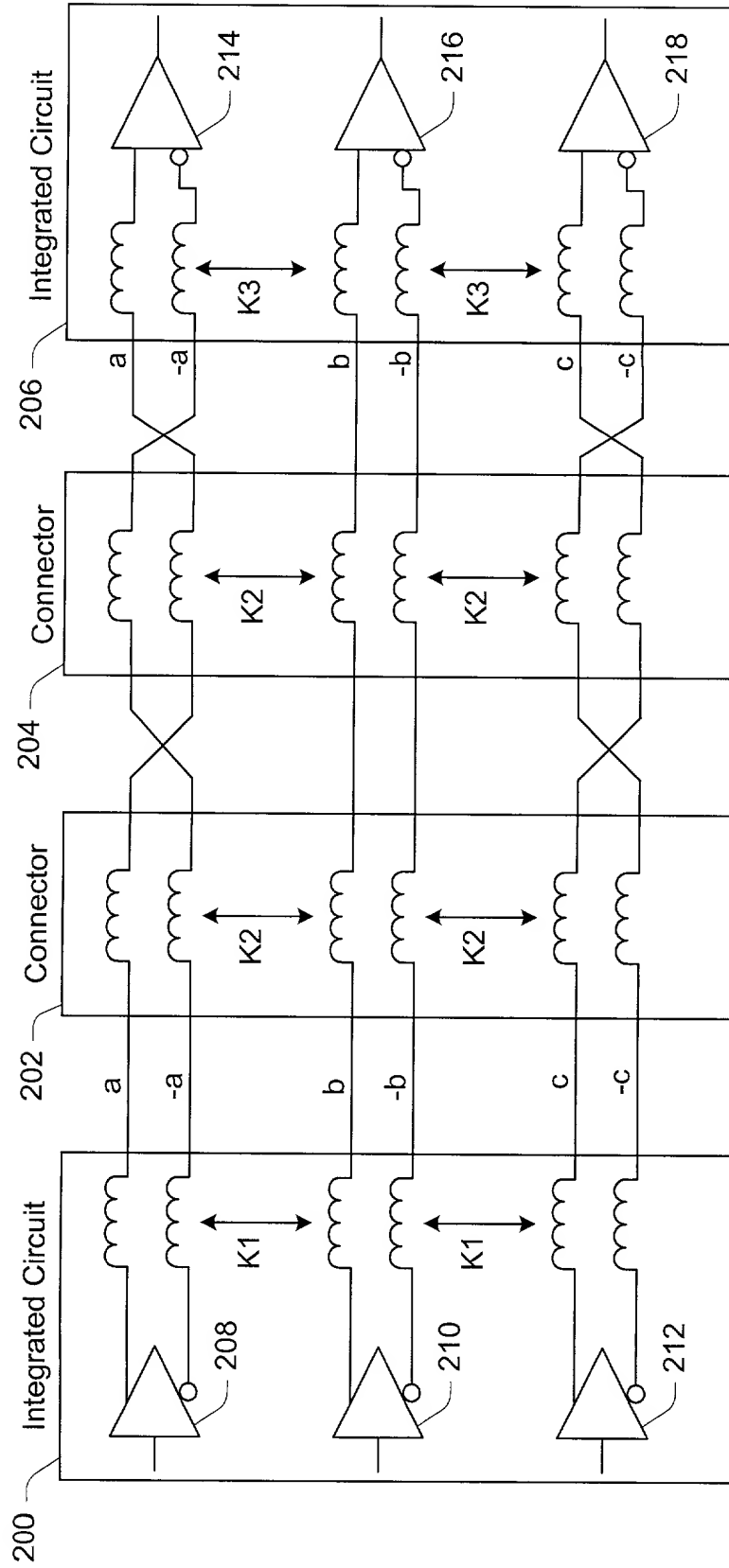


Fig. 2

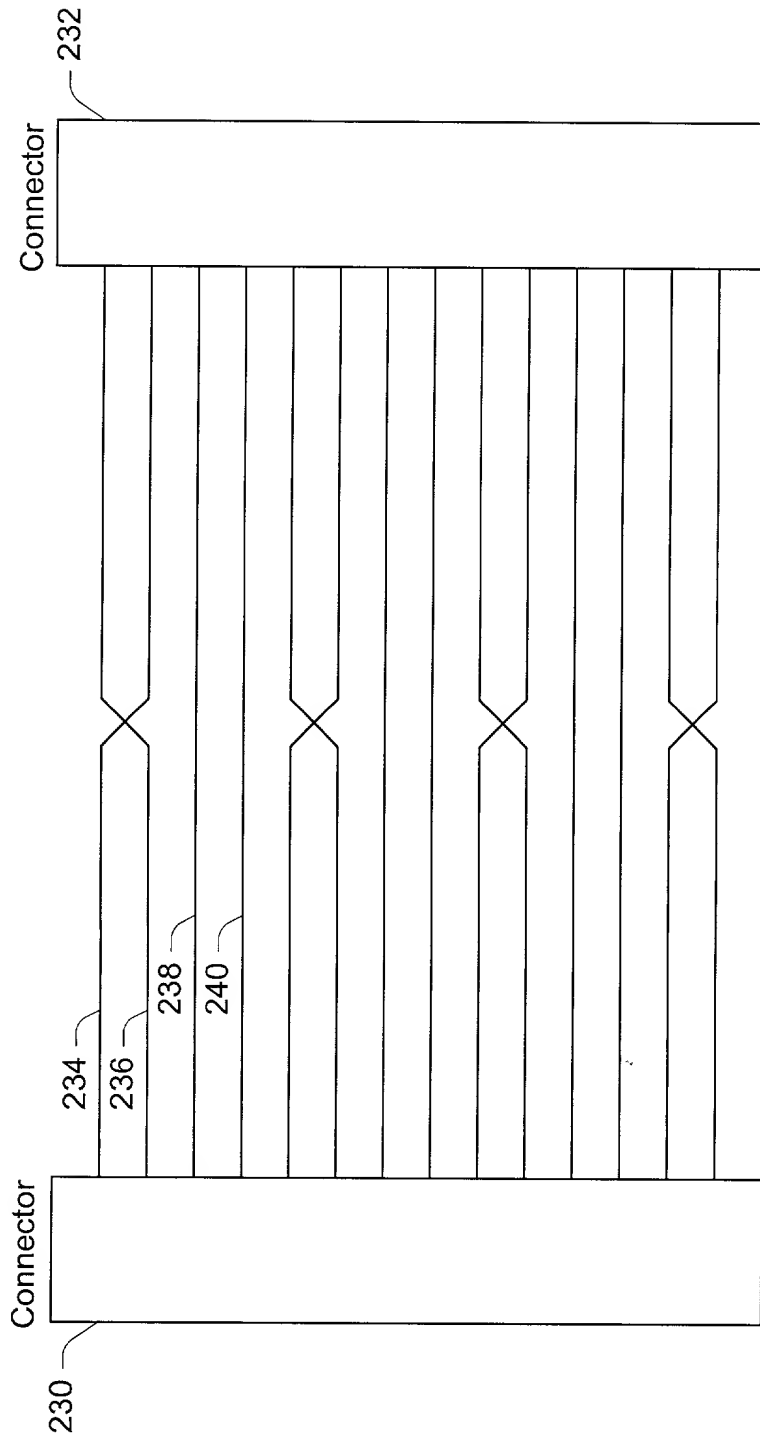
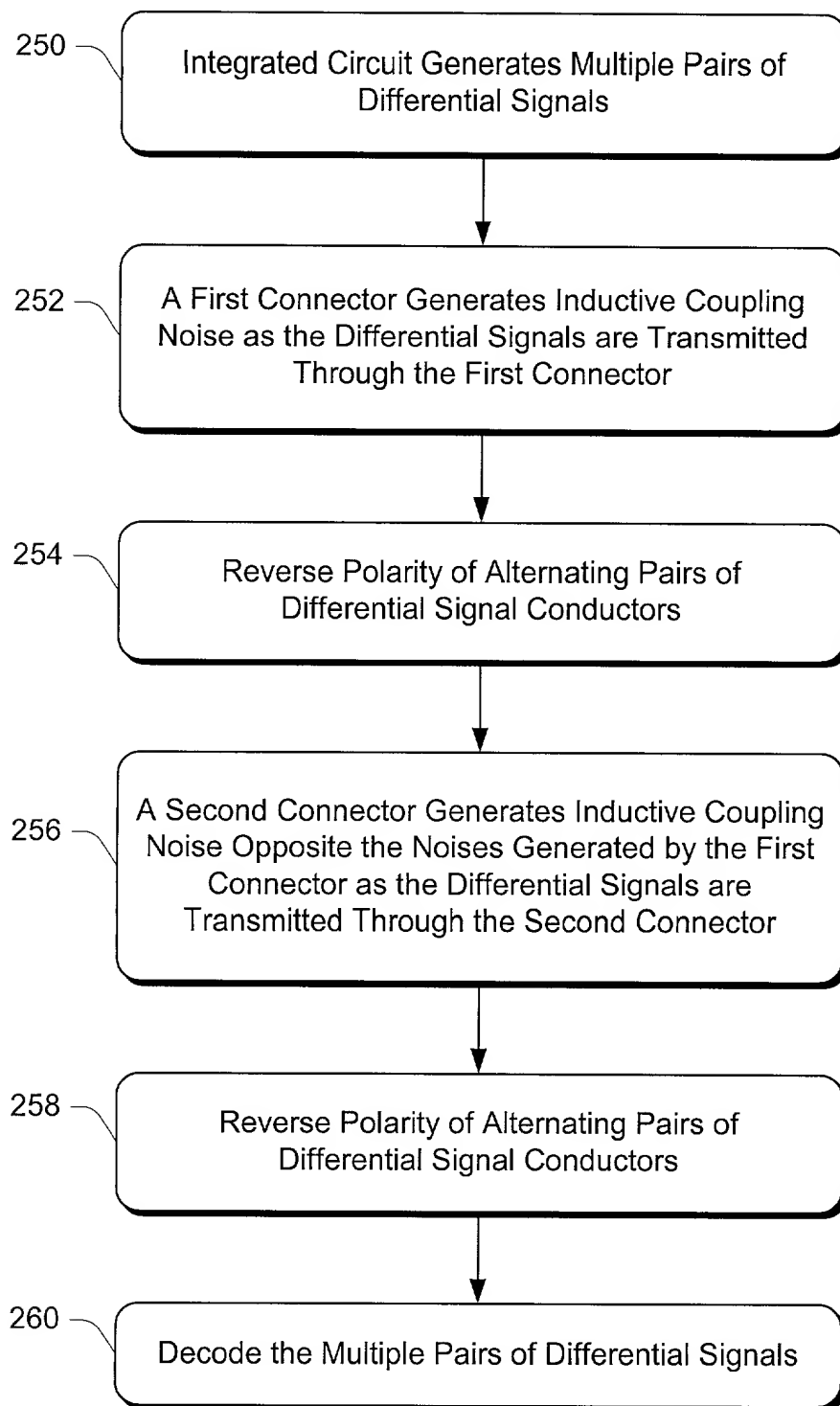
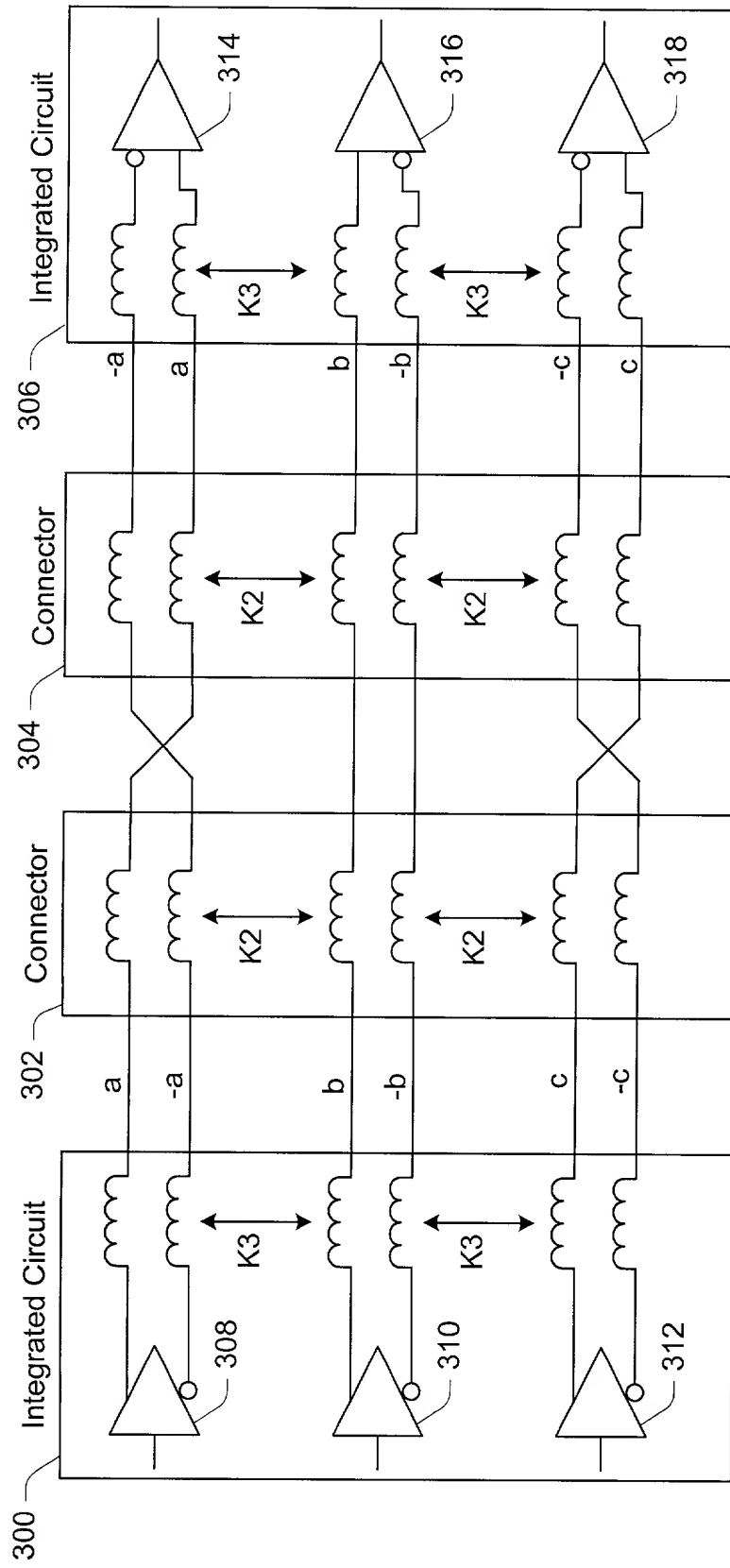
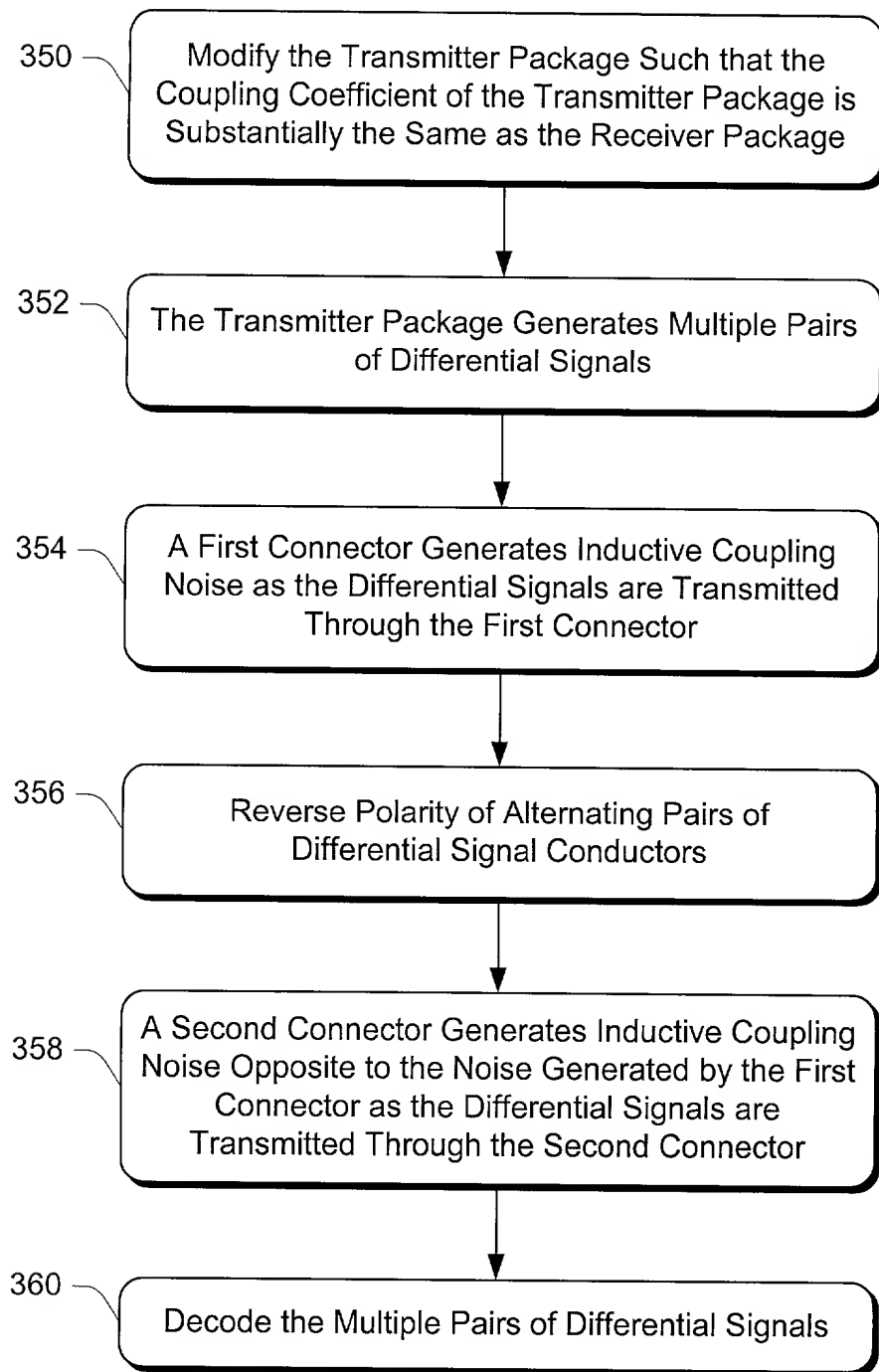


Fig. 3

*Fig. 4*

*Fig. 5*

*Fig. 6*

1 **IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

2 Inventorship Horowitz et al.
3 Applicant Rambus Inc.
4 Attorney's Docket No. RB1-003US
5 Title: Method and Apparatus for Transmitting Data with Reduced Coupling Noise

6 **DECLARATION FOR PATENT APPLICATION**

7 As a below named inventor, I hereby declare that:

8 My residence, post office address and citizenship are as stated below next to
9 my name.

10 I believe I am the original, first and sole inventor (if only one name is listed
11 below) or an original, first and joint inventor (if plural names are listed below) of the
12 subject matter which is claimed and for which a patent is sought on the invention
13 entitled "Method and Apparatus for Transmitting Data with Reduced Coupling
14 Noise," the specification of which is attached hereto.

15 I have reviewed and understand the content of the above-identified
16 specification, including the claims.

17 I acknowledge the duty to disclose information which is material to the
18 examination of this application in accordance with Title 37, Code of Federal
19 Regulations, § 1.56(a).

20 PRIOR FOREIGN APPLICATIONS: no applications for foreign patents or
21 inventor's certificates have been filed prior to the date of execution of this
22 declaration.

23 **Power of Attorney**

24 I appoint the following attorneys to prosecute this application and transact all
25 future business in the Patent and Trademark Office connected with this application:
26 Lewis C. Lee, Reg. No. 34,656; Daniel L. Hayes, Reg. No. 34,618; Allan T.

1 Sponseller, Reg. 38,318; Steven R. Sponseller, Reg. No. 39,384; James R.
2 Banowsky, Reg. No. 37,773; Lance R. Sadler, Reg. No. 38,605; Michael A. Proksch,
3 Reg. No. 43,021; Thomas A. Jolly, Reg. No. 39,241; Kasey C. Christie, Reg. No.
4 40,559 and David A. Morasch, Reg. No. 42,905.

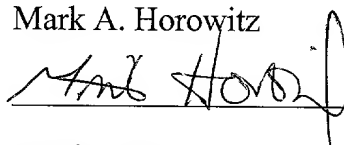
5 Send correspondence to: LEE & HAYES, PLLC, 421 W. Riverside Avenue,
6 Suite 500, Spokane, Washington, 99201. Direct telephone calls to: Steven R.
7 Sponseller (509) 324-9256.

8
9 All statements made herein of my own knowledge are true and that all
10 statements made on information and belief are believed to be true; and further that
11 these statements were made with the knowledge that willful false statements and the
12 like so made are punishable by fine or imprisonment, or both, under Section 1001 of
13 Title 18 of the United States Code and that such willful false statement may
14 jeopardize the validity of the application or any patent issued therefrom.

15
16 * * * * *

17 Full name of inventor: Mark A. Horowitz

18 Inventor's Signature



Date: 6/9/00

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